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Differential FDG-PET Uptake Patterns in Uninfected and Infected Central Prosthetic Vascular Grafts

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WHAT THIS PAPER ADDS

FDG-PET scanning is a new tool for the diagnosis of central vascular graft infections. However, little is known about which FDG uptake patterns are associated with uncomplicated central vascular graft implantations. This paper is the first to study the typical FDG uptake patterns of uninfected and infected grafts, offering information which may influence the further use of FDG-PET scanning in the diagnosis of vascular graft infections.

Objective: ^{18}F-fluorodeoxyglucose (FDG) positron emission tomography (PET) scanning has been suggested as a means to detect vascular graft infections. However, little is known about the typical FDG uptake patterns associated with synthetic vascular graft implantation. The aim of the present study was to compare uninfected and infected central vascular grafts in terms of various parameters used to interpret PET images.

Methods: From 2007 through 2013, patients in whom a FDG-PET scan was performed for any indication after open or endovascular central arterial prosthetic reconstruction were identified. Graft infection was defined as the presence of clinical or biochemical signs of graft infection with positive cultures or based on a combination of clinical, biochemical, and imaging parameters (other than PET scan data). All other grafts were deemed uninfected. PET images were analyzed using maximum systemic uptake value (SUVmax), tissue to background ratio (TBR), visual grading scale (VGS), and focality of FDG uptake (focal or homogenous).

Results: Twenty-seven uninfected and 32 infected grafts were identified. Median SUVmax was 3.3 (interquartile range [IQR] 2.0–4.2) for the uninfected grafts and 5.7 for the infected grafts (IQR 2.2–7.8). Mean TBR was 2.0 (IQR 1.4–2.5) and 3.2 (IQR 1.5–3.5), respectively. On VGS, 44% of the uninfected and 72% of the infected grafts were judged as a high probability for infection. Homogenous FDG uptake was noted in 74% of the uninfected and 31% of the infected grafts. Uptake patterns of uninfected and infected grafts showed a large overlap for all parameters.

Conclusion: The patterns of FDG uptake for uninfected vascular grafts largely overlap with those of infected vascular grafts. This questions the value of these individual FDG-PET-CT parameters in identifying infected grafts.

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Keywords: PET-scan, Vascular graft infections, FDG-uptake patterns

INTRODUCTION

Central vascular prosthetic graft (CVG) infections are associated with morbidity and mortality rates of up to 50%.[1–3] As the diagnosis often leads to substantial surgical procedures, obtaining proof of the infection is essential. Symptoms are often non-specific, thus the diagnosis relies heavily on medical imaging.[4] While a false negative test result may lead to under-treatment, a false positive test result may lead to unnecessary surgery. Considering the vulnerable patient population, any mis-classification of the test outcomes will have a negative impact on the prognosis. Therefore, a diagnostic tool is needed with the ability to discriminate well between the presence and the absence of a CVG infection.

Recently, positron emission tomography scanning (PET scan) using ^{18}F-fluorodeoxyglucose (FDG) has been suggested to be valuable in the diagnostic process of CVG infections.[5–9] ^{18}F-FDG PET scanning is based on the uptake of radioactive labeled ^{18}F-FDG (a glucose analog) in metabolically active cells. Infectious and inflammatory processes show uptake of FDG.[10]

Synthetic vascular grafts have been shown to provoke a chronic low grade inflammation which is a potential uptake

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source for FDG.[11] FDG uptake has also been shown to occur in uninfected aortic vascular grafts. However, little is known about "normal" FDG uptake patterns, associated with the implantation of a synthetic vascular graft.[6,10,12–14] Therefore, the aim of this study was to assess the FDG uptake patterns in uninfected and infected CVG, comparing maximum standardized uptake value (SUVmax), tissue to background ratio (TBR), visual grading scale (VGS), and focality of FDG uptake between uninfected and infected central vascular grafts.

MATERIAL AND METHODS

Patients treated by open or endovascular central vascular reconstructions in a tertiary referral center were retrospectively included from January 1, 2007 to December 31, 2013. Patients were identified through the hospital registration system using the Dutch financial codes for open and endovascular central vascular reconstructions (Appendix I). Central vascular grafts were defined as non-peripheral vascular grafts and contained (1) open and/or endovascular central vascular reconstructions; (2) abdominal grafts; (3) thoracic grafts; and (4) centrally located extra-anatomic reconstructions (axillo-femoral reconstructions and femoro-femoral reconstructions). All surgical reports were reviewed to identify patients meeting these inclusion criteria. Strictly infra-inguinal grafts were excluded.

This dataset was merged with the local nuclear medicine registration system to identify patients in whom a FDG-PET scan was performed, irrespective of the indication for imaging. Only patients in whom a FDG-PET scan was performed *after* graft implantation, for any indication, were included in the present study. Incomplete PET scans were excluded (Fig. 1).

Basic patient characteristics and data on the primary aortic reconstruction were recorded. Comorbidities were defined as recommended by the Ad Hoc Committee on Reporting Standards.[15] The medical records were searched for clinical signs of infection (body temperature above 38.5 °Celsius, fluid surrounding the graft, incisional fistula, exposed grafts, and deep wound infections) at the time of the PET scan. Laboratory infection parameters at the time of the PET scan

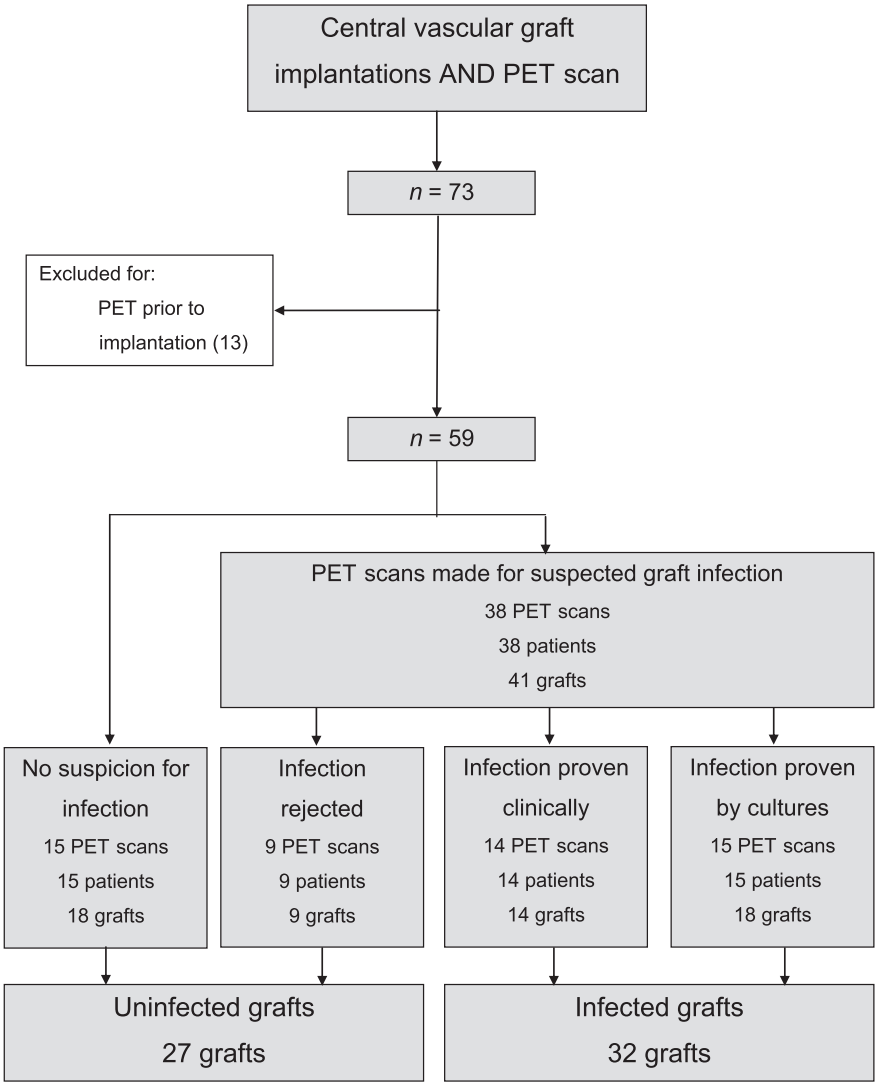

Figure 1. Data collection.

were recorded (white blood cell counts, C-reactive protein, sedimentation rate, positive blood cultures).

Uninfected was defined as absence of clinical and biochemical signs of graft infection or ultimate rejection of vascular graft infection by a combination of biochemical, clinical, and imaging parameters (other than PET scan) despite initial positive clinical or biochemical signs of a graft infection. Infection was defined as the presence of clinical or biochemical signs of a graft infection with positive cultures or based on a combination of clinical, biochemical, and imaging parameters (other than PET scan data). In case of multiple grafts, each graft was scored separately. Only the first PET scan after graft implantation was scored (Fig. 1).

FDG-PET imaging

FDG-PET scans were acquired using a FDG-PET scanner (Siemens Biograph Sensation 16, Germany). Subjects received an intravenous injection of FDG at 2.0 MBq/kg of body weight. Patients were hydrated with 1000 mL of water 1 hour prior to image acquisition. Blood glucose levels were checked in all patients before FDG injection, and no patients had blood glucose levels greater than 160 mg/dL. Approximately 1 hour after FDG injection, the FDG-PET scan was performed. An emission PET scan was obtained with 3 minute acquisitions per bed position using a 3 dimensional acquisition mode. After PET scanning a low dose CT was performed for attenuation correction. In case of multiple grafts, all grafts were scored separately.

Image analysis

All images were analyzed by two independent, experienced nuclear medical physicists (NMP) on a digital workstation, blinded for the clinical data. The following features were used to further analyze and quantify the images: SUVmax, TBR, VGS, and focality of FDG uptake (focal or homogenous) TBR was defined as SUVmax divided by SUVmax of the bloodpool. The intensity of FDG uptake was graded on a 5 point scale (VGS) as follows:

> grade 0: FDG uptake similar to that in the background
> grade 1: low FDG uptake, comparable to that of inactive muscles and fat
> grade 2: moderate FDG uptake, clearly visible and higher than the uptake by inactive muscles and fat
> grade 3: strong FDG uptake, but distinctly less than the physiological urinary uptake by the bladder
> grade 4: strong FDG uptake, comparable with the physiological urinary uptake by the bladder.[5]

Based on the visual grading scale, the probability of prosthetic infection on FDG-PET scanning was classified as low or high (visual grades 0, 1, or 2 were defined as low, visual grades 3 or 4 were defined as high). Focal FDG uptake was defined as well circumscribed areas of increased uptake in connection with the graft. For the final conclusion, a 5 point Likert scale was used: clearly not infected, probably not infected, doubtful, probably infected, and clearly infected.[16,17] Examinations were reviewed in three orthogonal views. Fused PET/CT images were used to correlate the PET signal with morphological findings. In all examinations, 1 cm or larger circular regions of interest (ROIs) were drawn. Differences of opinion between the observers with regard to the VGS, focality, and final conclusion were resolved by discussion and ended in a consensus.

Statistical analysis

Baseline characteristics were presented as median and interquartile range (IQR) or percentages. Differences between the uninfected and infected graft groups were tested using the independent *t* test and chi-square test. For SUVmax and TBR, a receiver operating characteristic (ROC) curve was plotted and the AUC (area under the ROC curve) with 95% CI was calculated. Using the cutoff point with the highest sensitivity and specificity from the AUC curves, a threshold value for SUVmax and TBR was determined. Data were calculated for both observers. Means and standard deviations between both observers were very much equal. Correlations were 0.83 and 0.84, respectively. Because of these high correlations and the fair amount of agreement between observers, only data from observer 1 are presented. Where opinions on VGS, focality, and final conclusion differed, they were resolved by discussion, leading to a consensus. Three subgroup analyses were performed: aortic grafts (defined as grafts with at least one aortic anastomosis), extra anatomic/subcutaneous grafts, and early (within 1 year after implantation) versus late PET scans.

Data were collected and processed using the Statistical Package for the Social Sciences version 20.0 (SPSS, IBM, Armonk, NY, USA).

Data were analyzed anonymously and retrospectively. Retrospective patient data research does not fall under the scope of Dutch law on human research, therefore ethical approval was not required.

RESULTS

Seventy-three patients with a central vascular graft implantation underwent PET scanning for various reasons. After excluding incomplete scans and scans made prior to graft implantation, 53 patients with 59 grafts (53 PET scans) were included in the present study. None of the included patients had had previous operations for vascular graft infections at other institutions. There were 27 uninfected grafts and 32 infected grafts. Patients with uninfected grafts had a median age of 69.3 years (IQR 57.3—70.7) and consisted of 22 (82%) males. Patients with infected grafts had a median age of 66.0 years (IQR 55.5—68.2) and consisted of 22 (69%) males. The indications for PET scans for the uninfected grafts were malignancy ($n = 18$, 67%), suspected vascular graft infection ($n = 7$, 26%), and unknown infection ($n = 2$, 7%). In the latter two groups ($n = 9$) an infection was ruled out. All PET scans in the infected group were performed for a suspected vascular graft infection. Median time between graft implantation and PET scan was 4.3 years

(IQR 2.7—7.9) for the uninfected grafts and 3.9 years (IQR 0.6—6.9) for the infected grafts. Patient characteristics are shown in Table 1. The sedimentation rate was statistically significantly higher in the infected graft group as well as clinical parameters ($p < .05$). In both the uninfected and infected groups, the predominant indication for central vascular reconstruction was an abdominal aortic aneurysm (63%). Details on the surgical procedures are shown in Table 2. Most patients underwent separate computed tomography (CT) scanning around the time of PET scanning. Table 3 shows the different CT parameters and the correlation with the PET results.

Maximum standardized uptake value (SUVmax)

Median SUVmax was 3.3 (IQR 2.0—4.2) for the uninfected grafts and 5.7 for the infected grafts (IQR 2.2—7.8). AUC was 0.80 (95% CI 0.67—0.93). Using a cutoff value of 5.5 yielded a sensitivity of 80% (95% CI 60—100%), and specificity of 81% (95% CI 69—93%). Fig. 2 shows that the SUVmax distributions for the uninfected and infected grafts largely overlap.

Table 1. Basic patient characteristics.

	Uninfected grafts (No, %)	Infected grafts (No, %)
Total number of grafts, *n*	27	32
Age, years (mean ± SD)	69.3 ± 9.3	66.0 ± 8.1
Male sex	22 (82)	22 (69)
Comorbidities		
Smoking	12 (48)	18 (60)
Diabetes	3 (11)	4 (13)
Hypertension	9 (33)	16 (50)
Cardiac (SVS class 1,2 or 3)	9 (33)	14 (44)
Pulmonary (SVS class 1,2 or 3)	9 (33)	5 (16)
Laboratory parameters		
Leucocytes, $*10^9$/L, mean (range, SD)	9.3 (4—15.6, 3.3)	9.1 (2.9—18.6, 3.3)
C-reactive protein, mg/L, mean (range, SD)	55.8 (8—144, 55.0)	47.4 (5—162, 40.1)
Sedimentation, mm after 1 hour, mean (range, SD)	16.8 (7—42, 16.9)	64.7 (8—140, 38.2)
Clinical and CT parameters		
Positive blood cultures	0	9 (28)
Fever	0	24 (75)
Incisional fistula	0	8 (25)
Exposed graft	0	5 (16)
Fluid surrounding graft	0	11 (34)
Air surrounding graft	0	7 (22)
>20 HU peri-graft soft tissue	3 (11)	19 (59)
Time between graft implantation and PET scan, years, mean (range)	4.3 (0.0—14.2)	3.9 (0.0—20.2)
Indication for PET scan		
Malignancy	18 (67)	0
Suspected graft infection	7 (26)	32 (100)
Unknown infection	2 (7)	0

CT = computed tomography; HU = Hounsfield units; SVS = Society for Vascular Surgery.

Table 2. Surgical procedures.

	Uninfected grafts, *n* (%)	Infected grafts, *n* (%)
Operation indication		
Aortic aneurysm	17 (63)	20 (63)
Stenosing aortic disease	10 (37)	7 (22)
Other	0	5 (16)
Operation type		
Aorta		
Tube	4 (15)	4 (13)
Aorto-bi-iliac	4 (15)	5 (16)
Aorto-bi-femoral	6 (22)	5 (16)
Aorto-uni-iliac-uni-femoral	0	1 (3)
Ilio-femoral	1 (4)	3 (9)
Extra-anatomic bypass		
Axillo-bi-femoral	1 (4)	3 (9)
Axillo-uni-femoral	1 (4)	0
Axillo-popliteal	0	3 (9)
Femoro-femoral crossover	5 (19)	1 (3)
EVAR		
Bifurcation	3 (11)	5 (16)
Aorto-uni-iliac with femoro-femoral crossover	2 (7)	1 (3)
TEVAR	0	1 (3)

EVAR = endovascular aneurysm repair; TEVAR = thoracic endovascular aneurysm repair.

Tissue to background ratio (TBR)

Median TBR was 2.0 (IQR 1.4—2.5) for the uninfected grafts and 3.2 for the infected grafts (IQR 1.5—3.5). The AUC was 0.76 (95% CI 0.62—0.89). Using a cutoff value of 3 yielded a sensitivity of 73% (95% CI 51 96%), specificity of 71% (95% CI 58—85%). Fig. 3 shows the TBR distributions for uninfected and infected grafts to be largely overlapping.

Visual grading scale (VGS)

Fig. 4 shows the results of the VGS. VGS was subdivided into low probability for AGI (VGS 0, 1, and 2) and high probability (VGS 3 and 4). This yielded a sensitivity of 72% (95% CI 56—89%) and specificity of 56% (95% CI 37—74%).

Focality

A focal FDG uptake was observed in 26% of the uninfected compared with 69% of the infected grafts (Fig. 5). Focality

Table 3. CT findings and correlation with PET studies.

	Uninfected grafts	Infected grafts	Negative PET result	Positive PET result
Peri-graft air	0	7	0	7
No peri-graft air	4	15	7	12
Peri-graft fluid	0	11	0	11
No peri-graft fluid	3	12	7	8
>20 HU peri-graft soft tissue	3	19	7	15
<20 HU peri-graft soft tissue	1	3	1	3

HU = Hounsfield units.

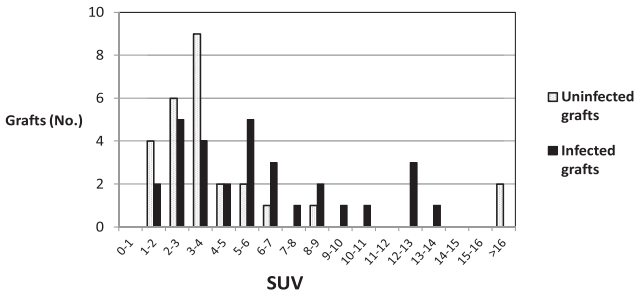

Figure 2. SUVmax distribution in uninfected and infected grafts.

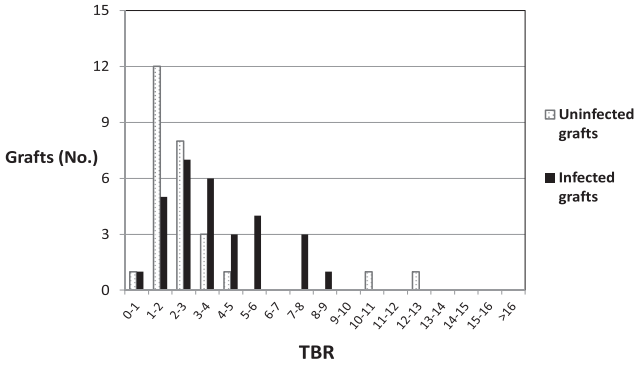

Figure 3. TBR distribution in uninfected and infected grafts.

as a parameter to detect AGI yielded a sensitivity of 66% (95% CI 48—83%) and specificity of 74% (95% CI 58—91%).

Final conclusion based only on imaging

The final conclusion of the PET scans was made using all available PET information (SUVmax, TBR, VGS, and focality).

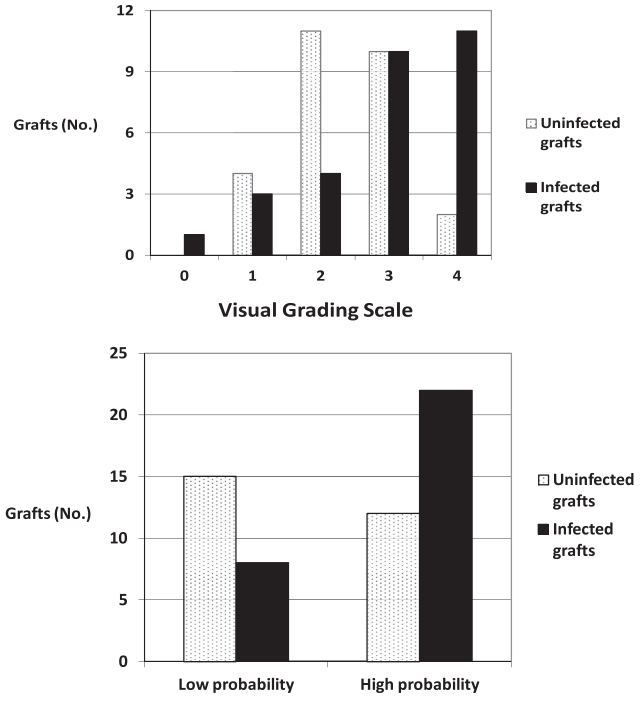

Figure 4. Visual grading scale distribution in uninfected and infected grafts.

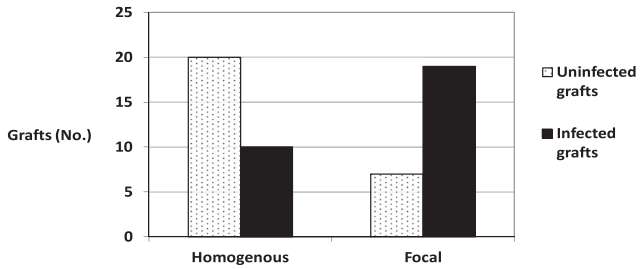

Figure 5. Homogenous and focal FDG uptake in uninfected and infected grafts.

Most of the uninfected grafts were judged clearly not infected or probably not infected (24 out of 27, 89%). Most of the infected grafts were judged clearly infected or probably infected (21 out of 32, 66%) (Fig. 6). Subdividing the conclusion into uninfected (clearly uninfected or probably uninfected) and infected (doubtful, probably infected, or clearly infected) yielded a sensitivity of 77% (95% CI 62—92%) and a specificity of 89% (95% CI 77—100%).

Aortic grafts

The distributions of SUVmax, TBR, VGS, focality, and the final conclusion also largely overlapped in uninfected ($n = 14$) and infected grafts ($n = 15$), when the analysis was restricted to aortic grafts (supplemental Figures S1—S5).

Subcutaneous grafts

The distributions of SUVmax, TBR, VGS, focality, and the final conclusion also largely overlapped in uninfected ($n = 7$) and infected grafts ($n = 7$), when the analysis was restricted to extra anatomic, subcutaneous grafts (supplemental Figures S6—S10).

Early versus late PET scans. An early PET scan within 12 months of graft implantation was performed in six uninfected grafts and 12 infected grafts. A late PET scan was performed in 21 uninfected and 20 infected grafts. The qualitative parameters in this subgroup analysis showed the same overlap as for the total group. In the early group, the VGS detected all six uninfected grafts (100%). Of the early infected grafts, 82% showed focal uptake. Of the uninfected grafts in the early groups, 100% could be identified by the final conclusion. In the late group, the same overlap between uninfected and infected grafts was seen for SUVmax,

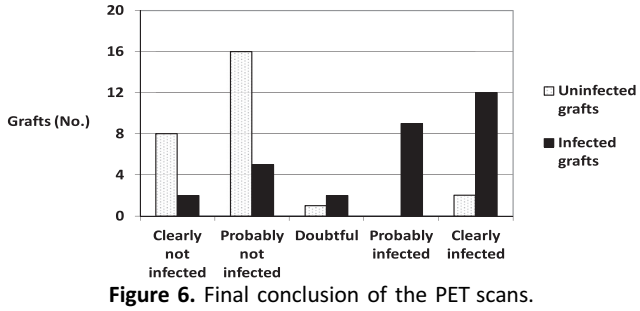

Figure 6. Final conclusion of the PET scans.

TBR, VGS, focality, and the final conclusion as for the total group.

DISCUSSION

This study reports the distribution of SUVmax, TBR, VGS, focality of FDG uptake, and final conclusion in uninfected and infected central vascular grafts (CVG). It is the first to show that FDG uptake patterns in uninfected CVGs largely overlap with those of infected CVGs.

Only limited studies have shown that uninfected grafts are indeed able to display FDG uptake. One study reported on 16 patients with aortic grafts in which FDG uptake was demonstrated in 11, while only one of these grafts was deemed infected.[14] In another study, 102 PET scans in 42 patients with 107 uninfected vascular grafts were analyzed.[10] FDG uptake was noted in 98 grafts (92%). The amount of FDG uptake can be expressed by SUVmax and TBR. The role of SUVmax and TBR in diagnosing increased FDG uptake has not been established for uninfected or infected grafts. Considering the large overlap of SUVmax and TBR in uninfected and infected grafts in the present study, cutoff values will be difficult to establish.

Of the quantitative parameters used to interpret PET images, only focal uptake has been shown to accurately predict infection.[8,18] In a series by Keidar et al., a diffuse homogenous uptake was noted in 67 uninfected grafts (63%) and inhomogenous uptake was noted in 31 grafts (29%). No grafts displayed focal FDG uptake.[10] In the present study, however, focal and homogenous FDG uptake were observed in both uninfected and infected central vascular grafts. Spacek et al. reported that focal uptake was associated with a vascular graft infection with a sensitivity of 78% (95% CI 67—89%) and specificity of 93% (95%CI 85—100%). These estimates could not be reproduced in the present study (sensitivity of 66%, 95% CI 48—83%, and specificity of 74%, 95% CI 58—91%). One important difference between the study by Spacek et al. and the present study is the definition of proven graft infection. While in the present study, a graft infection was considered proven on microbiological or clinical parameters, Spacek et al. used positive microbiological or histopathological findings. This may have led to an underestimation of infections in the latter study.

No quantitative parameter of the FDG-PET scan could be identified that could reliably differentiate between uninfected and infected grafts. This limits the usefulness of these individual parameters in identifying infected grafts. Of the qualitative parameters, only the final conclusion seemed to be able to provide some differentiation. There is no clear explanation for this finding. Apparently, the individual parameters add up to a subjective threshold above which a graft is deemed either uninfected or infected. Multivariate analysis with a larger patient population with different weighting schemes of the individual parameters is required to explain this issue.

In the present study, two different groups were created. It may be debated whether three different groups (non-infected, proven infected, or suspicious graft infections) would better reflect clinical reality. The non-infected group would have been straightforward, containing only patients with a malignancy. The proven infected group, however, would pose some problems. Cultures are the gold standard to prove infection but the use of antibiotics and biofilm forming microorganisms limits the value of cultures in graft infections. By including only culture proven infections in the proven infection group, some high grade infections, the clinical infections, and some low grade infections would be missed. This would underestimate the true incidence of graft infection and inflate the suspicious graft infection group. Together with the risk of ending up with small numbers, it was decided to cluster the patients with proven infection and compare those with proven uninfected grafts.

In the present study a standard interval between FDG administration and the start of PET acquisition (60 minutes) was used. Although some authors mention the possible added value of late FDG-PET imaging for infection detection, this is mostly based on case studies and most evidence for late FDG-PET imaging is aimed at malignancy. The current guidelines for FDG-PET imaging therefore do not advocate late imaging for infection detection.

It can be postulated that concomitant pathologies, like malignancies or cardiovascular diseases influence graft FDG uptake. However, as uptake in large tumors for instance, does not affect normal FDG uptake in the liver, muscles, and brain, it is unlikely that concomitant uptake will influence the uptake in the vascular grafts.

The strengths of this study are that it is the first study to describe the FDG uptake patterns in uninfected and infected central vascular grafts, it compares SUVmax, TBR, VGS, and focality of FDG uptake in uninfected and infected central vascular grafts, and all PET-FDG parameters were independently assessed by two observers, blinded for clinical data. The following limitations of this study need to be addressed. First, normal FDG uptake patterns may differ according to graft location. In the present study stent grafts, subcutaneous grafts, as well as aortic grafts were included. The numbers in the present study were too small to determine differences in uptake patterns, stratified for graft location. With the low incidence of aortic graft infections (AGI), a (inter)national registry would probably be the only way to analyze uptake patterns in the different graft groups. However, the present subgroup analysis of aortic and subcutaneous grafts showed the same overlap between FDG uptake patterns of uninfected and infected grafts as for the total group. The small numbers in the present study illustrates the difficulties of research on graft infections. A graft infection registry may prove valuable for further research on FDG uptake patterns in uninfected vascular grafts. Second, different graft materials provoke different inflammatory reactions and may therefore yield a different normal FDG uptake pattern. All the aortic and subcutaneous grafts in the present study, however, were made of polyester. The effect of graft material on normal uptake patterns will probably be mild in the present study. Third, in the present study patients with different anatomical configurations, clinical situations, and operative details were analyzed as a

group, as a concession to statistical limitations. Despite lumping together these clinically very different procedures, the present analyses display some important messages, which should be further addressed in future and more specific studies. Fourth, there was a large range between implantation and PET scanning. This means that patients were analyzed during different stages of infection or inflammation. In an ideal study set up, multiple scans would be performed at fixed times (e.g. 1, month, 3 month, 1 year). However, this study used retrospective registry data, which reflect daily clinical practice but also imply that the time between operation and PET scan can vary considerably between patients.

Finally, only the first PET scan performed after central aortic graft implantation was assessed. The temporal changes of FDG uptake patterns in the immediate post-operative period have not been studied. The healing of the surgical trauma associated with a vascular graft implantation is characterized by several inflammatory stages. After the first hemostatic phase, the inflammatory phase occurs, which lasts for up to a couple of weeks. As FDG accumulates in inflammatory cells, these phases are associated with an increased FDG uptake. This uptake is generally said to be mild to moderate. After this phase the proliferation phase begins, in which new granulation tissue is created and angiogenesis takes place. Theoretically this phase can also show an increased FDG uptake. Although this uptake is probably less than that of the inflammatory phase, a PET scan during this phase can potentially induce false positive results. After these three phases, remodeling occurs. This is only a very mild inflammatory phase which can last for a prolonged period of time. The peak of inflammatory FDG uptake in the post-operative phase therefore occurs during the first couple of weeks, during which the value of a PET scan in the diagnosis of vascular graft infections is diminished. Larger studies are needed to assess the effect of post-operative timing of the PET scan on the normal FDG uptake patterns. Larger studies are needed to assess the effect of post-operative timing of the PET scan on the normal FDG uptake patterns.

CONCLUSIONS

Patterns of FDG uptake in uninfected grafts largely overlap with those of infected vascular grafts. This limits the diagnostic value of the individual parameters of the PET scan (SUVmax, TBR, VGS, and focality of FDG uptake) in identifying or ruling out infected grafts. To further specify the potential of FDG PET scanning, more data are needed on the normal uptake patterns associated with vascular graft implantation. A larger study is needed, in which potential confounding factors are ruled out. Ideally this should be a study in which only patients with a specific graft location and graft material are included and compared during a predetermined post-operative period.

CONFLICT OF INTEREST

None.

FUNDING

None.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ejvs.2015.06.007

APPENDIX I. FINANCIAL CODES USED FOR PATIENT SELECTION

Code	Surgical procedure
333152Y	Aorta, operative treatment traumatic aorta rupture, thoracic, endovascular bifurcation graft
333153A	Aorta, operative treatment thoracic aneurysm, non-ruptured, tube graft
333153B	Aorta, operative treatment thoracic aneurysm, ruptured, tube graft
333153C	Aorta, operative treatment abdominal-thoracic aneurysm, non-ruptured, tube graft
333153D	Aorta, operative treatment abdominal-thoracic aneurysm, non-ruptured, bifurcation graft
333153E	Aorta, operative treatment abdominal-thoracic aneurysm, ruptured, tube graft
333153F	Aorta, operative treatment abdominal-thoracic aneurysm, ruptured, bifurcation graft
333153H	Aorta, thoracic aneurysm, percutaneous prosthesis
333530E	Aorta, operative treatment abdominal aneurysm, non-ruptured, tube graft
333530F	Aorta, operative treatment abdominal aneurysm, non-ruptured, bifurcation graft
333530H	Aorta, operative treatment abdominal aneurysm, non-ruptured, endovascular bifurcation graft
333530K	Aorta, operative treatment abdominal aneurysm, ruptured, bifurcation graft
333530J	Aorta, operative treatment abdominal aneurysm, ruptured, tube graft
333530N	Aorta, operative treatment abdominal aneurysm, endovascular tube graft
333530P	Aorta, operative treatment abdominal aneurysm, ruptured, endovascular bifurcation graft
333545A	Iliac artery, operative treatment iliac aneurysm, non-ruptured
333545B	Iliac artery, operative treatment iliac aneurysm, ruptured
333551A	Mesenteric artery, reconstruction, synthetic interposition graft
333552	Aortoiliac bypass graft
333552B	Mesenteric artery, reconstruction, synthetic bypass graft
333552C	Aorta, aorto-femoral bypass
333553	Aorta, tube graft
333558	Aorta, aorto-iliac-aorto-ilio-femoral bifurcation graft
333594	Aorta, excision infected prosthetic aorto/iliac graft
333672	Axillo-popliteal bypass
333673	Femoro-femoral bypass
333674C	Obturator bypass
333679	Iliac artery, Iliaco-femoral bypass

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